

UNITED STATES DEPARTMENT OF THE INTERIOR
MINERALS MANAGEMENT SERVICE
GULF OF MEXICO REGION

ACCIDENT INVESTIGATION REPORT

1. OCCURRED

DATE: 19-APR-2009 TIME: 1530 HOURS

2. OPERATOR: LLOG Exploration Offshore, Inc.

REPRESENTATIVE: Paternostro, Barney

TELEPHONE: (504) 833-7700

CONTRACTOR: NOBLE DRILLING (U.S.) INC.

REPRESENTATIVE: Brunson, Dan

TELEPHONE: (281) 276-6607

- ☐ STRUCTURAL DAMAGE
☐ CRANE
☐ OTHER LIFTING DEVICE
☐ DAMAGED/DISABLED SAFETY SYS.
☒ INCIDENT >\$25K 200 bbls 14.4 ppg CaBr2
☐ H2S/15MIN./20PPM
☒ REQUIRED MUSTER
☐ SHUTDOWN FROM GAS RELEASE
☐ OTHER

3. OPERATOR/CONTRACTOR REPRESENTATIVE/SUPERVISOR
ON SITE AT TIME OF INCIDENT:

6. OPERATION:

4. LEASE: G08483

AREA: MC LATITUDE:

BLOCK: 72 LONGITUDE:

- ☐ PRODUCTION
☐ DRILLING
☐ WORKOVER
☒ COMPLETION
☐ HELICOPTER
☐ MOTOR VESSEL
☐ PIPELINE SEGMENT NO.
☐ OTHER

5. PLATFORM:

RIG NAME: NOBLE LORRIS BOUZIGARD

6. ACTIVITY: ☐ EXPLORATION (POE)
☒ DEVELOPMENT/PRODUCTION
(DOCD/POD)

8. CAUSE:

7. TYPE:

- ☐ HISTORIC INJURY
☐ REQUIRED EVACUATION
☐ LTA (1-3 days)
☐ LTA (>3 days)
☐ RW/JT (1-3 days)
☐ RW/JT (>3 days)
☐ Other Injury

- ☒ EQUIPMENT FAILURE
☐ HUMAN ERROR
☐ EXTERNAL DAMAGE
☐ SLIP/TRIP/FALL
☐ WEATHER RELATED
☐ LEAK
☐ UPSET H2O TREATING
☐ OVERBOARD DRILLING FLUID
☒ OTHER procedural

- ☐ FATALITY
☒ POLLUTION
☐ FIRE
☐ EXPLOSION

9. WATER DEPTH: 2013 FT.

10. DISTANCE FROM SHORE: MI.

11. WIND DIRECTION:
SPEED: M.P.H.

12. CURRENT DIRECTION:
SPEED: M.P.H.

13. SEA STATE: FT.

- LWC ☐ HISTORIC BLOWOUT
☐ UNDERGROUND
☐ SURFACE
☐ DEVERTER
☒ SURFACE EQUIPMENT FAILURE OR PROCEDURES

COLLISION ☐ HISTORIC ☐ >\$25K ☐ <=\$25K

17. INVESTIGATION FINDINGS:

On 19 March 2009 at approximately 1530 hours, a well control event occurred aboard the Noble semi-submersible rig Lorris Bouzigard (the rig) on the LLOG Exploration Offshore, Inc. (LLOG), Lease OCS-G 8483, Mississippi Canyon (MC) Block 72, Gulf of Mexico (GOM), offshore the State of Louisiana.

Subsequent to the well being perforated, reverse circulated and monitored in a static condition, the Tubing Conveyed Perforating Work String (workstring) was lifted with 5,000 pounds of over-pull to release the CHAMP IV Packer and set the workstring in the slips. Within minutes of rigging down surface lines a 10 barrel (bbl) trip tank gain was observed. The workstring was lifted for proper spacing across the Subsea BOP stack and both the BOP Upper Annular and rig floor Drill String Safety Valve (DSSV) were closed with the well continuing to flow. The diverter elements were closed and both 12-inch diverter valves opened, while the riser was continuously boosted with 14.4 pounds per gallon (ppg) CaBr₂ to prevent riser collapse. The BOP Lower Annular and BOP Upper Pipe Ram were then closed with the well continuing to flow. With an initial choke manifold pressure of 6,700 psi the BOP Middle Ram was closed. Drilling personnel estimated that approximately 200 bbl of riser was discharged through both 12-inch diverter lines into the GOM within 20 minutes of the upper annular closure. The gas-cut CaBr₂ blew the master rotary bushing out of the rotary table onto its side on the rig floor and non-essential personnel were mustered at the stern life boat stations donning life jackets as the general evacuation alarm sounded, but no actual rig evacuation was required. The rig's personnel described the diverter flow noise and vibration as increasing to a "deafening roar".

Bullheading operations were initiated down the kill line utilizing the 14.4 ppg CaBr₂ completion fluid when the DSSV located in the workstring was discovered to be pressure-locked. A hot tap beneath the DSSV was installed by Wild Well Control Inc. (WWCI) below a 5 inch drill pipe tool joint and 3,000 psi was bled-off. Approximately 1-1/2 workstring volumes of 14.4 ppg CaBr₂ was circulated down the workstring and up the annulus, while the riser was continuously filled with completion fluid, until the well was determined to be static. Approximately 1,200 psi of trapped pressure was bled from between the middle ram and upper pipe ram through the choke line, well kill operations were completed with the SBOP stack swept of any remaining gas and the riser was continuously filled to remain static. Subsequent to well kill operations the well was frac packed and the remaining completion operations performed without any further incident.

18. LIST THE PROBABLE CAUSE(S) OF ACCIDENT:

No clear and specific cause could be identified for the gas bubble to have traveled into the riser prior to the first surface observed trip tank gain and closure of the BOP Upper Annular subsequent to intentionally unseating the Champ IV Packer. Two (2) possible causes that may have prompted the event are presented below.

* Unintentional momentary opening of the Champ IV Packer's concentric by-pass valve and/or relaxation of the Champ IV Packer's sealing element subsequent to perforating:

1. It is possible for the reverse shock wave created by the 86 feet of 7-inch hollow carrier perforating guns to result in momentarily opening of the Champ IV Packer's concentric by-pass valve and/or relaxation of the Champ IV sealing elements. This would allow for a gas bubble flow path to the annulus above the Champ IV Packer. The ShockPro™ simulation program estimated ½ inch of workstring upward movement, while

the Champ IV Packer and Champ IV Packer's concentric by-pass valve are designed to open with approximately 5.5 inches and 2 inches of upward movement, respectively. At the moment of perforating there is a drop in hookload, but the scale used on the Driller's P-V-T screen makes it difficult to determine the order of magnitude of the drop. In addition, it is possible that some portion of the hookload decrease is attributed to the pressure applied to the work string and not just the shock force from the perforating guns. Lastly, shop post-testing and observation of the Champ IV Packer indicated sealing element damage to include cracking and bubbling and a significant amount of material removed from the top of the Champ IV Packer's sealing element.

2. At 1250 hours (approximately 3 minutes after the perforating guns fire) the work string down-hole BHP reading at the start of the first cycle of the OMNI Valve is approximately 200 psi less than the BHP pressure gauge reading prior to closing the BOP Upper Annular and testing the Champ IV Packer before perforating. After final cycling of the OMNI Valve at approximately 1305 hours, the BHP pressure gauge reading continued to increase steadily, the standpipe pressure increased by approximately 200 psi and the pit volume increased 10 bbl from 620-630 bbl; all indications of possible annular formation gas migration.

3. The elapsed time from when the well was perforated to flow being observed at the trip tank was approximately 2 hours and 47 minutes from 1247-1534 hours, indicating a possible formation gas migration rate of approximately 4,650 feet per hour. This assumes, however, that the formation gas migration rate or slippage occurred against the reverse circulation pump rate of 5 bpm = 6,450 feet per hour in the 9-5/8-inch casing. This gas migration rate would have put the gas bubble at the closed BOP Upper Annular in approximately 2 hours and 15 minutes. The elapsed time from perforating to opening the BOP Upper Annular in order to unseat the Champ IV Packer was approximately 2 hours and 30 minutes. Therefore, the formation gas could have entered the riser from being trapped below the closed BOP Upper Annular or within minutes of unseating the Champ IV Packer after the BOP Upper Annular was opened.

4. Gas slippage through another fluid has been known to occur without causing a pit gain and fluid moving in one direction resulting in an adjacent fluid to move in the opposite direction. If formation gas had been present and it reached the subsea BOP stack subsequent to closure of the BOP Upper Annular, the gas would have accumulated between the kill line inlet and closed BOP Upper Annular. It took approximately 200 bbl to fill the riser subsequent to the well unloading. Using this gas volume at ambient conditions, the gas bubble would be less than one bbl at down-hole conditions and on the order of 7.6 bbl when it reaches the subsea BOP stack. There is approximately 24 feet (7.5 bbl cavity) between the point of closure of the BOP Upper Annular and the entry point of the kill line. This 7.5 bbl cavity is a dead zone which cannot be swept by the circulating fluid, thus allowing any accumulated gas to remain trapped in place until the BOP Upper Annular was opened. Gas bubble slip velocity, unfortunately, is difficult to model as it is influenced by bubble size and the size of the gas void fraction (ratio or percentage of the gas cross-sectional area to the total flow area), wellbore geometry and inclination, fluid density differences, fluid viscosity and circulation rate.

Therefore, possible formation gas influx from momentary opening of the Champ IV Packer's concentric by-pass valve and/or relaxation of the Champ IV Packer's sealing element subsequent to perforating, in conjunction with formation gas migration (slippage), is concluded to be a possible cause of the incident.

* Intentional elimination of the second reverse circulation step subsequent to unseating the Champ IV Packer:

The completion procedure proposed a second reverse circulation step subsequent to releasing the Champ IV Packer in order to remove any gas influx that might have been trapped under the Champ IV Packer during perforating. Subsequent to the well going on vacuum following perforating, in addition to determining that the well was static subsequent to opening the Champ IV Packer's bypass and unseating the Champ IV Packer, the decision was made by LLOG to eliminate the second reverse circulation operation. At 1534 hours when the Champ IV Packer was unseated, the P-V-T system graph data shows

that the pit volume increased 5 bbl to 620 bbl and the trip tank volume increased 3 bbl to 29 bbl. In addition, when the Champ IV Packer was unseated the work string down-hole internal pressure gauges equalized to a pressure less than the reservoir pressure, thereby indicating possible gas influx into the well. From 1529-1541 hours the pit volume increases 64 bbl from 615-679 bbl while the work string down-hole temperature gauges reflect an increasing temperature trend from 210 degrees Fahrenheit (F) to a maximum temperature of 230 degrees F as the hotter formation fluid was entering the wellbore. Although any possible gas front subsequent to immediately releasing the packer would not have reached the riser during the time the diverter flow event occurred, elimination of the second reverse circulation might have further complicated the well kill operation through any possible additional formation gas influx/migration. Therefore, elimination of the completion procedure's proposed second reverse circulation step subsequent to unseating the Champ IV Packer is concluded to be a possible cause of the incident.

19. LIST THE CONTRIBUTING CAUSE(S) OF ACCIDENT:

There are three (3) possible contributing causes as follows:

- * Considering the loss of hydrostatic head as a result of the well going on a vacuum subsequent to perforating, in addition to the 230 bbl of 14.5 ppg Synthetic Base Mud loss during the open-hole drilling of the zone of interest, the lack of spotting a high-viscosity completion fluid brine pill utilizing bridging agents across the proposed interval prior to perforating is concluded to be a possible contributing cause.
- * The wide scale range (-10 to 600 bbl) on the Driller's P-V-T screen made it difficult to observe the 5 to 20 bbl pit volume slope gains that occurred at different times leading up to the diverter flow event.
- * The lack of a consistently "closed" fluid system, as a result of several lines rigged-up to the trip tank to provide multiple pumping and flowing paths in/out of the wellbore, fluid being moved throughout the system (to a filter unit, to the Halliburton unit, filling/draining surface lines, and general semi-submersible rig movement), and undocumented trip tank piping arrangement during the different phases of the operation are concluded to be a possible contributing cause of the incident.

20. LIST THE ADDITIONAL INFORMATION:

OMNI Valve:

The integrity of the OMNI Valve was confirmed subsequent to perforating and prior to POOH by flow chart recordings and successful shifting of the OMNI Valve into the blank position (ball valve closed and circulating ports closed). While the OMNI Valve was not available for post-event investigation (the tool had been redressed upon returning to the Halliburton shop), its pressure sealing integrity and functionality were verified through down-hole pressure data analyses charts and graphs provided by Halliburton. In addition, Halliburton states that during redressing of the tool, no parts were in need of replacement other than the standard changing of all o-ring seals. Subsequent to redressing, both a successful pressure and function test was also performed on the tool with post-job test results provided.

TP-Pro program:

The TP-Pro program calculates the thermal expansion and pressure compressibility behavior of clear brine fluids in a well bore, since solid-free brines susceptibility to thermal expansion and pressure compressibility can alter the effective down-hole density of the brine. The results are based on best available information while assuming both equilibrium and static well conditions. The program's worksheet summary indicates that a three (3)-salt fluid composition was utilized to develop the 14.4 ppg CaBr₂ selected surface density which was equivalent to an effective 14.35 ppg CaBr₂

density at the depth of the perforations (perforating approximately 214 psi overbalanced). During the MMS review and discussion with the TETRA Engineering Manager, it was determined that the 14.4 ppg CaBr₂ completion fluid used in the completion was blended from a single (1)-salt blend composition of 346 ppb CaBr₂ (54.8 weight %) and the 3-salt composition indicated on the worksheet summary was actually a typographical error. Subsequent to the MMS's request that the TP-Pro program be run utilizing a 1-salt system, the output results generated on 4 May 2009 indicated no change from the 3-salt composition when compared to the 1-salt composition. It was also determined that the completion fluid used on the well was pre-mixed at the TETRA blending facility in Port Fourchon, Louisiana and transported by boat to the rig site with a density of 14.37 ppg that was verified by the onsite Fluid Engineer.

The effect of pressure raising the apparent crystallization temperature on high density brines has been established by industry. Drilling in deep waters, and particularly subsea completions, provides the conditions that can significantly raise the crystallization points of heavy brines. Blend density was utilized to determine the crystallization properties of the 1-salt fluid. The True Crystallization Temperature (TCT) of the blended fluid was measured in the TETRA Quality Assurance/Quality Control process to be less than 10 degrees F with a Pressured Crystallization Temperature (PCT) of 10,000 pounds per 30 degrees F.

21. PROPERTY DAMAGED:

NATURE OF DAMAGE:

Approximately 200 bbl of lost 14.4 ppg CaBr₂.

Diverted overboard.

ESTIMATED AMOUNT (TOTAL):

\$71,000

22. RECOMMENDATIONS TO PREVENT RECURRENCE NARRATIVE:

The MMS Office of Safety Management (OSM) recommends a Safety Alert be forwarded to industry describing the diverter flow event and possible cause, with the following recommendations to Operators and/or Lessees:

- * Spotting of a high-viscosity completion brine pill utilizing bridging agents prior to perforating proposed completion zones that experienced significant open-hole drilling fluid losses.
- * Monitoring work string and annular pressures closely for any anomalies in order to isolate any possible work string to annular communication prior to proceeding with the proposed completion.
- * Sweeping of the subsea BOP stack on wells when formation fluids are expected or known to have entered the wellbore and/or when the BOP has been activated for any purpose other than testing.
- * Bullheading or a second reverse circulation should be considered after unseating the work string packer subsequent to perforating in order to control any possible formation influx below the packer.
- * Special attention should be given to the down-hole perforating forces and the possibility of these forces opening a packer's by-pass valve and/or relaxing the work string packer's sealing elements to allow formation fluid into the annulus above the packer.
- * Maintaining the surface fluid system as "closed" as possible, since fluid being moved throughout the surface system (filling/draining lines and other equipment tanks, semi-submersible rig movement, etc.) makes subtle trip tank and pit

gains/losses more difficult to accurately monitor. Also, documenting the surface fluid system piping arrangement during the different phases of the operation can assist rig personnel in being cognizant of the flow path direction to more accurately analyze well flow data while possible providng more efficient well kill procedures.

* Ensuring that the scale used on the Driller's P-V-T screen is of a magnitude that can be used to readily observe subtle surface fluid system gains/losses.

23. POSSIBLE OCS VIOLATIONS RELATED TO ACCIDENT: **NO**

24. SPECIFY VIOLATIONS DIRECTLY OR INDIRECTLY CONTRIBUTING. NARRATIVE:

N/A

25. DATE OF ONSITE INVESTIGATION:

21-APR-2009

26. ONSITE TEAM MEMBERS:

**Frank Patton / Lance Labiche /
Randy Josey / Glynn T. Breaux /**

29. ACCIDENT INVESTIGATION

PANEL FORMED: **YES**

OCS REPORT: **see 2010**

30. DISTRICT SUPERVISOR:

J. David Dykes

APPROVED

DATE: **08-DEC-2009**

BLOWOUT ATTACHMENT

1. WELL NAME: **SS002** WELL NO.: **608174113700** LEASE: **G08483**

2. OPERATION: ☐ DRILLING ☒ COMPLETION
☐ WORKOVER ☐ PRODUCTION

3. SIMULTANEOUS OPERATIONS IN PROGRESS? **NO**

4. FLUID TYPE: **SEAWATER** WEIGHT: PPG

5. BOP STACK CONFIGURATION: SIZE: **18.75** IN
BOP Upper Annular PRESS RATING: **10000** PSI
BOP Lower Annular
BOP Shear Ram

6. BOP STACK - LAST TEST DATE PRIOR TO INCIDENT: **12-APR-2009** PRESSURE: **10000** PSI

7. LAST CASING STRING SET: FT SIZE: IN

8. SIZE OF DRILLING/WORKOVER STRING IN HOLE: **5.0** IN

9. KICK SIZE: **7** BBLS

10. FLUID KILL WEIGHT: PPG

11. INITIAL S.I.C.P.: PSI

12. S.I.D.P./W.S.P.: PSI

13. PRIOR HOLE PROBLEMS? **YES**

14. WELL CONTROL EQUIPMENT INITIALLY ACTIVATED:

<input checked="" type="checkbox"/> ANNULAR BOP	<input type="checkbox"/> SCSSV
<input type="checkbox"/> PIPE	<input type="checkbox"/> SSV
<input type="checkbox"/> BLIND	<input type="checkbox"/> OTHER _____
<input type="checkbox"/> BLIND SHEAR	

15. EVACUATION: **NO**

16. DIVERTER SYSTEM VALVE SIZE: **12**
LINE SIZE: **12**

☐ SINGLE SPOOL
☒ DUAL SPOOL

17. WAS WELL DIVERTED? **YES**

18. BOTTOM HOLE ASSEMBLY:
N/A-Gravel Pack Assembly

19. DRILLING DEPTH: TVD MD

20. DATE LAST FORMATION INTEGRITY TEST:
13-JAN-2008

21. SSSV TYPE: **TIW**

DATE LAST TESTED: **13-APR-2009**

22. TREE: ON ☐ OFF ☒

23. SURFACE SAFETY EQUIPMENT IN SERVICE? **NO**

24. WELL TD: TVD MD

25. OPEN PERF? **YES**

POLLUTION ATTACHMENT

1. VOLUME:	GAL	200	BBL
	YARDS LONG X		YARDS WIDE

APPEARANCE:

2. TYPE OF HYDROCARBON RELEASED:

<input type="checkbox"/>	OIL
<input type="checkbox"/>	DIESEL
<input type="checkbox"/>	CONDENSATE
<input type="checkbox"/>	HYDRAULIC
<input type="checkbox"/>	NATURAL GAS
<input checked="" type="checkbox"/>	OTHER <u>14.4 ppg CaBr2</u>

3. SOURCE OF HYDROCARBON RELEASED: **completion fluid from riser**

4. WERE SAMPLES TAKEN? **YES**

5. WAS CLEANUP EQUIPMENT ACTIVATED? **NO**

IF SO, TYPE: ☐ SKIMMER

☐ CONTAINMENT BOOM

☐ ABSORPTION EQUIPMENT

☐ DISPERSANTS

☐ OTHER

6. ESTIMATED RECOVERY: 0 GAL BBL

7. RESPONSE TIME: HOURS

8. IS THE POLLUTION IN THE PROXIMITY OF AN ENVIRONMENTALLY SENSITIVE AREA (CLASS I)? **NO**

9. HAS REGION OIL SPILL TASK FORCE BEEN NOTIFIED? **NO**

10. CONTACTED SHORE: **NO** IF YES, WHERE:

11. WERE ANY LIVE ANIMALS OBSERVED NEAR: **NO**

12. WERE ANY OILED OR DEAD ANIMALS OBSERVED NEAR SPILL: **NO**

